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Suborbital Flights: Environmental Concerns and Regulatory Iniatives

S. M. Mousavi Sameh

SUBORBITAL FLIGHTS: ENVIRONMENTAL CONCERNS AND REGULATORY INITIATIVES

S. M. Mousavi Sameh*

I. INTRODUCTION

SCALED COMPOSITES' *SpaceShipOne* successfully completed two suborbital flights to an altitude of 100 kilometers within a two week period, for which the company was subsequently awarded the Ansari X-Prize,[1] which was a milestone in the history of human flight. Since then, important steps have been taken to promote ambitious plans for safe and affordable human access to the Earth's suborbit, with such plans only now coming to fruition. Suborbital flights are not limited to tourism purposes, as there are also long-term projects for developing suborbital Earth-to-Earth transportation systems via high-technology reusable hybrid vehicles.

These technological initiatives and ventures regarding the commercialization of Earth's suborbital stratum give rise to a variety of legal issues and considerations. The reality of suborbital flight, for example, fosters a debate over which legal regime is or should be applicable to such flights, and international law presently does not provide clear answers to the legal challenges that may arise with the operation of suborbital vehicles. The conceptually challenging legal questions with respect to the suborbital flight industry, if we may call it this, concern issues as

* S. M. Mousavi Sameh has earned her Master's Degree in Air and Space Law (2013) from McGill University in Montreal, Canada. She holds a Master's Degree in International Law (2008) and has received her LL.B. from the University of Tehran. She has been a member of the Central Bar Association of Iran since 2008. She is completing a certificate program pursuant to which she will be admitted to the Bar of Quebec, Canada. She is a research assistant at the Institute of Air & Space Law and has recently completed an internship in the Legal Affairs and External Relations Bureau of International Civil Aviation Organization.

1 Leonard David, *SpaceShipOne Wins $10 Million Ansari X Prize in Historic 2nd Trip to Space*, SPACE.COM (Oct. 4, 2004, 10:56 AM), http://www.space.com/403-spaceshipone-wins-10-million-ansari-prize-historic-2nd-trip-space.html [https://perma.cc/XQ56-CHK3].

broad and varied as nationality and registration, licensing and certification, safety, security, liability, traffic management systems, and environmental protection.

Among the aforementioned areas, environmental issues with respect to operation of suborbital flights, which directly affect the sustainability of the nascent industry of suborbital flights, are addressed less in the scholarly research already conducted regarding the legal issues of suborbital flights. The international community is increasingly vigilant about the threats that human activities pose to the environment, and suborbital flights should be brought into line with the efforts being made to find the most practical and efficient measures for reducing anthropogenic negative effects on the Earth's environment and, more recently, outer space. Thus, in this context, it is necessary not only to ask whether suborbital vehicles have climate-friendly technologies, but also to determine the appropriate legal framework for the regulation of the environmental impact of suborbital flights. Analysis of such concerns is also important because dealing with consequences that result from a problem after it emerges is always more difficult than using forward-looking approaches and taking proactive precautionary measures. This is especially true of environmental protection, which is a vital and inseparable part of sustainable development.[2] Indeed, in many instances, the environmental movement activists' efforts to bring their concerns to the general population's attention have been both insufficient and overdue to be truly effective.

The purpose of this article is to provide an overview of the environmental issues associated with the operation of suborbital flights and to advance the discussions of possible regulatory scenarios on the environmental aspects of these flights. While some scholars have suggested that it is necessary to choose either the air or space legal regimes as the competent regime to regulate this emergent technology, it is argued here that choosing one of the two regimes to regulate suborbital flights might not be the best approach, at least when it comes to environmental protection.

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[2] MARK WILLIAM, SPACE: THE FRAGILE FRONTIER 242 (2006); MALGOSIA FITZMAURICE, CONTEMPORARY ISSUES IN INTERNATIONAL ENVIRONMENTAL LAW 67–87 (2009). "In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it." U.N. Conference on Environment and Development, *Rio Declaration on Environment and Development*, U.N. Doc. A/CONF.151/26/Rev.1 (Vol. I), princ. 4 (Aug. 12, 1992) [hereinafter *Rio Declaration*].

II. SUBORBITAL VEHICLES AND TECHNICAL CHARACTERISTICS

Vehicles designed for suborbital flights are of different designs and technologies. They do not operate exactly like an aircraft or a space object. In other words, suborbital vehicles are neither pure aircraft nor pure spacecraft; instead, they consist of some characteristics of both.[3] Moreover, as is clear from the current existing and proposed designs, suborbital vehicles are intended to operate in both airspace and outer space. For example, in the case of *SpaceShipOne* and its successor vehicle, *SpaceShipTwo*, there is a ballistic portion of the flight when the vehicle is not supported by the reactions of the air. This occurs when the vehicle reaches the upper atmosphere where the air density is no longer sufficient for aerodynamic flight.[4] In addition to dual environments of operation, the proposed suborbital aerospace vehicle designs include varied possibilities for the "ascent" and "descent" phases. Ascent in suborbital vehicles involves two major types of horizontal or ballistic aerospace vehicles.[5] This means that the vehicle might ascend in a horizontal take-off or be launched from an aircraft, such as from *WhiteKnightTwo*, a custom jet aircraft built with four engines and a spacious attachment area in the center. Alternatively, the vehicle could use rocket propulsion for a vertical take-off. Similarly, as with the ascent phase, there are two possibilities for the descent: (a) to return the vehicle to the location from where it started or (b) to return the vehicle to a different location on Earth, also known as point-to-point suborbital transportation.[6] With respect to the design of *SpaceShipOne*, for example, the vehicle transitions to unpowered aerodynamic flight (gliding) for re-entry into the atmosphere on its return to Earth, during which it can be compared to an aircraft.[7] However, because this is a new technology with an unprecedented combination of two

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[3] George Paul Sloup, *The NASA Space Shuttle and Other Aerospace Vehicles: A Primer for Lawyers on Legal Characterization*, 8 CAL. W. INT'L L.J. 407, 415 (1978); *Concept of Sub-Orbital Flights* 2.3 (Int'l Civ. Aviation Org. (ICAO), Working Paper No. C-WP/12436, 2005) [hereinafter *Concept of Sub-Orbital Flights*, ICAO Working Paper].

[4] *Concept of Sub-Orbital Flights*, ICAO Working Paper, *supra* note 3, at 2.2.

[5] Tanja Masson-Zwaan & Steven Freeland, *Between Heaven and Earth: The Legal Challenges of Human Space Travel*, 66 ACTA ASTRONAUTICA 1597, 1599 (2010).

[6] *Id.* at 1599–1600; Stephan Hobe, *Legal Aspects of Space Tourism*, 86 NEB. L. REV. 439, 440 (2007). The U.S. space shuttle, however, acted like an aircraft (a glider) on its descent.

[7] *Concept of Sub-Orbital Flights*, ICAO Working Paper, *supra* note 3, at 2.2.

areas of operation in air and space, suborbital flights raise questions about the environmental effects of such flights. Moreover, the dual environments of operation for suborbital vehicles present the important question of what laws and regulations addressing environmental concerns ought to govern the operation of these hybrid vehicles.

III. SUBORBITAL FLIGHTS: AN ENVIRONMENTAL THREAT?

Although suborbital flights will soon be a routine part of tourism and the transportation industry, information about the possible contribution of suborbital flights to contamination of the Earth's atmosphere and outer space will not be available until the regular operation of such flights begin and assessment of the resulting pollution begins. Nevertheless, as is the case for environmental protection movements in every other sector, it is better to be proactive than take retroactive measures after the problem emerges. Moreover, if left unregulated, suborbital vehicles might become a source of environmental pollution in the future and could contribute to the already alarming levels of anthropogenic pollution in the atmosphere and outer space. The question is whether the existing environmental regulatory regimes are, or should be, applicable to the operation of suborbital flights or whether a new system should be designed to control the environmental effects of suborbital flights. As with any other case of environmental hazard, the first step in identifying the appropriate regulatory system to mitigate the environmental impacts of these vehicles is to examine the type of pollution they might create, with the next step being the quantification and assessment of such pollution.[8] Thus, it is necessary to analyze the possible environmental effects from the operation of suborbital vehicles in both levels in which they operate—the atmosphere and the Earth's suborbit. After the analysis, the regulations that may be applicable to control the environmental effects of suborbital flights will be reviewed.

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[8] *Assessing Current Scientific Knowledge, Uncertainties, and Gaps in Quantifying Climate Change, Noise and Air Quality Aviation Impacts*, FINAL REPORT OF THE ICAO COMMITTEE ON AVIATION AND ENVIRONMENTAL PROTECTION [CAEP] WORKSHOP, at iv–v (L.Q. Maurice et al. eds., 2009) [hereinafter *Assessing Climate Change, Noise & Air Quality Aviation Impacts*].

A. Ground and Atmospheric Impact

Considering the scientific uncertainty, informational problems, and the fact that suborbital vehicles are not yet in regular operation, it is difficult to assess the nature of possible environmental threats and the magnitude and extent of the risks caused by their emissions. However, there are some scientific facts that can help obtain an initial evaluation of the potential problems.

The trajectory for a suborbital airspace vehicle will extend virtually more than 100 kilometers, and the flight can have environmental effects while passing through different altitudes, from the ground through levels of the atmosphere to the edge of space and the Low Earth Orbit (LEO). Earth's atmosphere consists of different levels, which range from the troposphere to the exosphere, where the Earth's atmosphere ends.[9] Since most aviation activities include subsonic flights, aircraft emissions are currently released between the lower stratosphere and the troposphere.[10] This is not the case, however, for rockets and launching activities. Space activities begin on the Earth's surface and continue to outer space, crossing the various levels of the atmosphere in their trajectory. The effects include degradation of air quality in the troposphere (area from zero to sixteen kilometers above Earth), ozone depletion, climate change impacts in the stratosphere (area from sixteen to fifty kilometers above Earth), and other negative changes in the ionosphere and the thermosphere (area extending from 80 kilometers to about 600 kilometers above Earth).[11]

Suborbital vehicle emissions and noise problems will generally depend on the engines and kinds of designs used by the vehicles. Even if alleged to be environmentally friendly, the engines designed for these vehicles cannot be totally emission free because all types of propellants and different kinds of fuels contribute to environmental pollution. Indeed, even water vapor emissions have ozone depletion and climate change effects. In other words, no engine type is absolutely environmentally

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[9] *Atmospheric Layers*, Weather & Climate, http://www.weather-climate.org.uk/02.php [https://perma.cc/D4WX-Z2HL].

[10] "Aircraft typically operate at cruising altitudes of 8 to 13 km." *See* ICAO, *Environmental Report 2007*, at 105–06 (2007); *Scientific Assessment of Ozone Depletion: 2010*, Global Ozone Research and Monitoring Project—Report No. 52, World Meteorological Org. [WMO], ch. 5, at 5.24, http://www.esrl.noaa.gov/csd/assessments/ozone/2010/report.html [https://perma.cc/92F4-PFXH].

[11] *Atmospheric Layers*, *supra* note 9.

friendly.[12] As with aviation and launch activities, and the types of pollution of suborbital flights, the extent to which negative environmental effects may occur and the altitudes at which pollution occurs will depend on the technical characteristics and propulsion systems designed for the engines, the kind of ascent phase (horizontal or vertical), the kind of re-entry stage, the amount of fuel consumed, and the operational practices.[13] The vehicles operating with engines similar to those of aircraft burn different fuels and create different pollutants than do those operating with rocket engines. Regardless, to evaluate the environmental effects of suborbital flights, modeling and assessment techniques need to be developed. Similarly, when measuring engine fuel efficiency, many factors, including the amount of fuel consumed per unit of traffic carried, must be assessed.[14]

Some suborbital projects have been planned based on the use of jet and rocket engines for different phases of the flights, which include "horizontal take-off and landing," as well as the phase in which they reach space. Examples include the Virgin Galactic and EADS Astrium projects.[15] Virgin Galactic will use an air launch for its suborbital vehicle, *SpaceShipTwo*, from *WhiteKnightTwo*.[16] *SpaceShipTwo* will rely on a type of hybrid rocket engine, which uses a rubber compound as fuel and nitrous oxide as the oxidizer.[17] By comparison, the EADS Astrium project will employ standard jet engines for take-off and landing and a "methane oxygen rocket engine" for reaching the suborbit of the Earth, with all of the engines contained in one

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[12] Martin Ross et al., *Limits on the Space Launch Market Related to Stratospheric Ozone Depletion*, 7 ASTROPOLOTICS: THE INT'L J. SPACE & POL. 50, 52 (2009).

[13] The above-mentioned factors have been taken into account in different studies as the key factors influencing aviation and space activities' ground and atmospheric environment. *See generally* Intergovernmental Panel on Climate Change [IPCC], *IPCC Special Report: Aviation and the Global Atmosphere*, at 10 (1999) (Summary for Policymakers).

[14] *See* AIR TRANSPORT DEP'T, CRANFIELD UNIVERSITY, FUEL AND AIR TRANSPORT: A REPORT FOR THE EUROPEAN COMMISSION (2008), http://ec.europa.eu/transport/modes/air/doc/fuel_report_final.pdf [https://perma.cc/7LWA-CNAN].

[15] The EADS Astrium project for developing a suborbital vehicle has been suspended at the moment. *See* Jeff Foust, *Space Tourism: A European Perspective*, SPACE REV. (July 6, 2009), http://www.thespacereview.com/article/1411/1 [https://perma.cc/R6K9-R98W].

[16] *Our Vehicles: These Are the Vehicles That Will Take You to Space*, VIRGIN GALACTIC, http://www.virgingalactic.com/human-spaceflight/our-vehicles/ [https://perma.cc/ZZ3Q-Q34K].

[17] *Id.*

vehicle.[18] At the other end of the spectrum are projects involving designs with "vertical take-off and landing," which employ rocket fuels. Blue Origin's *New Shepard*, for example, is planned to be powered by "90-percent hydrogen peroxide and rocket grade kerosene."[19] Similarly, Armadillo, together with Space Adventures, is working on another suborbital vehicle project for tourism flights by developing ethanol and liquid oxygen-fueled engines.[20]

The companies that are currently designing suborbital vehicles have introduced their projects as environmentally friendly, and they refer to the reusability of the vehicles as a feature that considerably reduces their overall environmental harm.[21] As an example, Virgin Galactic argues that the vehicle it has designed is environmentally benign for a few different reasons. First, *SpaceShipTwo* and its carrier, *WhiteKnightTwo*, are being built from carbon composites, which are light and need less energy for propulsion compared to other materials.[22] Second, air launch itself has been introduced as a method whereby the air quality issues of ground-based launch are avoided, and the time

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[18] Eugene Kim, *EADS Astrium Space Tourism—A Space Plane That Takes Off and Lands at the Airport*, MY MODERN MET (Feb. 4, 2009), http://www.mymodernmet.com/profiles/blogs/eads-astrium-space-tourism-a [https://perma.cc/Y2B9-3J4Y].

[19] Hydro Kevin Kantola, *Hydrogen Peroxide Planes, Trains, and Automobiles*, HYDROGEN CARS NOW (May 7, 2007), http://www.hydrogencarsnow.com/index.php/hydrogen-vehicles/hydrogen-peroxide-planes-trains-and-automobiles/ [https://perma.cc/LA6M-8HPZ].

[20] Jon Cheng, *Welcome to the Future: Commercial Spaceport Makes Space Tourism a Reality,* TUFTS DAILY (Nov. 18, 2010), http://tuftsdaily.com/news/2010/11/18/welcome-to-the-future-commercial-spaceport-makes-space-tourism-a-reality/ [https://perma.cc/BAP5-3XHE}.

[21] *Environment: Making Space for Earth and the Environment, Overview of Virgin Galactic and its Project, 2009–2013*, VIRGIN GALACTIC, http://www.virgingalactic.com/overview/environment/ [https://perma.cc/R67C-X8GF]. In an opposite argument, reusable launch vehicles have been alleged to be more harmful to the environment. "The Space Shuttle emits several times more stratospheric emission per payload mass than the general trend for other launchers. Greater stratospheric emission for reusable launch vehicles (RLVs) compared to expendable vehicles would be characteristic of RLV systems in general and so in this sense RLVs are more harmful to ozone than expendables." Ross et al., *Limits on the Space Launch Market*, *supra* note 12, at 66.

[22] *Our Vehicles*, *supra* note 16. ICAO in its 2007 Environmental Report also refers to "the use of composites coupled with other advanced materials . . . systems optimizations, and new manufacturing techniques" as having "significant weight savings" results. *Environmental Report 2007, supra* note 10, at 132.

that the rockets burn the fuel is shortened.[23] Finally, *SpaceShipTwo* will have a hybrid motor that burns solid fuel with liquid oxidizer, which is alleged to be safer and less harmful to the environment than solid motors while possessing the efficiency of liquid engines.[24]

Notwithstanding these claims, there are environmental activists who are critical of suborbital flights. For example, in a report on the potential environmental impacts of suborbital flights presented to the American Geophysical Union in 2012, it was estimated that emissions from a fleet of 1,000 launches per year of suborbital rockets would create a persistent layer of black carbon particulates (BC)[25] in the northern stratosphere that could give rise to significant climate change in addition to stratospheric ozone depletion.[26] This report further asserted that the probable effect of this amount of BC is comparable to that emitted by the world's fleet of subsonic aircraft and that the result of such an amount of BC emissions could contribute to global warming at a level exceeding even that of the carbon dioxide emitted by rockets.[27] Similarly, while stratospheric emissions

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[23] Jeff Foust, *Air Launch, Big and Small*, SPACE REV. (June 30, 2014), http://www.thespacereview.com/article/2543/1 [https://perma.cc/336U-QL3X].

[24] There are three types of rocket propulsion: solid, liquid, and hybrid. In solid engines, fuel and the oxidizer needed for fuel combustion are in the form of solids and are mixed in a tube. Once ignited, they cannot be stopped, and they have more negative impacts on the environment. Liquid engines have both the fuel and oxidizer in the form of liquid, kept in separate storage. They are safer and less environmentally harmful, but they are more expensive. The third type is the hybrid engine, with solid fuel and liquid oxidizer. The advantage of these types of engines is that they are controllable and can be shut down whenever needed. *See generally* GEORGE P. SUTTON & OSCAR BIBLARZ, ROCKET PROPULSION ELEMENTS (8th ed. 2010); *Safety, The North Star, Overview of Virgin Galactic and its Project*, VIRGIN GALACTIC http://www.virgingalactic.com/overview/safety/ [https://perma.cc/P4L9-4W9N].

[25] Black carbon, in the Glossary of the Intergovernmental Panel on Climate Change (IPCC): Climate Change 2007, is defined as: "Particle matter in the atmosphere that consists of soot, charcoal[,] and/or possible light-absorbing refractory organic material. Black carbon is operationally defined matter based on measurement of light absorption and chemical reactivity and/or thermal stability." IPCC, *Climate Change 2007: Mitigation*: Contribution of Working Group III to the Fourth Assessment Report of the IPCC 810.

[26] Martin Ross et al., *Potential Climate Impact of Black Carbon Emitted by Rockets*, 37 GEOPHYSICAL RES. LETTERS 1, 2 (2010); *see also* M.Z. Jacobson, *Strong Radiative Heating Due to the Mixing State of Black Carbon in Atmospheric Aerosols*, 409 NATURE 695 (2001).

[27] Ross et al., *Potential Climate Impact*, *supra* note 26, at 9–11. The unique altitude, persistence, and asymmetric nature of the rocket-produced BC soot layer have been cited as possible reasons for such results and atmospheric response. *See*

from a single suborbital rocket are minimal, with frequent operation of the vehicles, the emissions and potential atmospheric impacts could become a concern.[28] The chosen propellant for suborbital vehicles produces emissions of BC directly into the upper stratosphere, and these emissions are capable of modifying the radiative properties of the atmosphere with larger amounts and longer lifetimes compared to those emitted from aircraft.[29] Regardless, because the information about the actual amount of emissions is presently uncertain and largely based upon assumptions rather than firm scientific data, one cannot speak decisively about the magnitude of the effects of BC on the environment.[30] On the other hand, some other studies refer to a possible increase in the emission of carbon dioxide if there is a growth of the suborbital flight industry in the future.[31] It has therefore been suggested that suborbital flight operators should consider making the whole experience "carbon neutral" to avoid criticism or opposition.[32] Nitrous oxide and methane, other proposed propellants for suborbital projects, are also key anthropogenic greenhouse gases with negative atmospheric effects.[33]

Considering that the vertical trajectory of a suborbital vehicle extends to at least 100 kilometers above the Earth, the potential impacts of suborbital flight on the upper levels of the atmosphere, other than the troposphere and stratosphere, must also be studied and assessed. Two other atmospheric levels that can potentially be influenced by the operation of suborbital vehicles

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id. at 11–12; *see also* Jacobson, *supra* note 26, at 695; *Scientific Assessment of Ozone Depletion: 2010*, *supra* note 10, at 5.25.

28 Ross et al., *Potential Climate Impact*, *supra* note 26, at 2.

29 "There are two main types of BC-emitting rocket engines, one burning kerosene and liquid oxygen and the other ("hybrid") burning solid HC (e.g. synthetic rubber or plastic) and N2O." *Id.* at 2–3.

30 IPCC, *Climate Change 2007: Mitigation*, *supra* note 25, at 193; Makiko Sato, *Global Atmospheric Black Carbon Inferred From AERONET*, 100 PROC. OF NAT'L ACAD. OF SCI. 6319, 6319 (2003); Jacobson, *supra* note 26, at 697.

31 Steven Fawkes, *Space Tourism and Carbon Dioxide Emissions*, SPACE REV. (Feb. 19, 2007), http://thespacereview.com/article/813/1 [https://perma.cc/LWC2-VZX5].

32 *Id.*

33 IPCC, 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES (Eggleston H.S. et. al. eds. 2006); Jonathan H. Adler, *Eyes on a Climate Prize: Rewarding Energy Innovation to Achieve Climate Stabilization*, 35 HARV. ENVTL. L. REV. 1, 5 (2011); Heather L. Miller, *Civil Aircraft Emissions and International Treaty Law*, 63 J. AIR L. & COM. 697, 701 (1998); ICAO, *Environmental Report 2007*, *supra* note 10, at 116.

are the thermosphere and the ionosphere. These levels start around 80 kilometers above the Earth and extend to about 500 to 640 kilometers.[34] It has been argued that as a result of anthropogenic pollutions, the thermosphere is becoming less dense, and carbon dioxide has a cooling effect on this level of the atmosphere.[35] This level of the atmosphere will thus drag satellites and other space objects in the LEO closer to the Earth. The amount of drag depends on the density of the thermosphere. If the density of the thermosphere changes constantly under the influence of human-caused emissions, satellite operators will need to be constantly observing and predicting the thermosphere's changes.[36] Likewise, the ionosphere could be affected by engine emissions. Chemicals such as nitrogen oxide, carbon dioxide, and hydrogen chloride reduce the density of the electrons in the ionosphere, and this reduction could change the radiowave-reflecting properties of the ionosphere, which in turn could distort radio communications.[37]

It appears that the negative effects of human activities on the upper levels of atmosphere, which until now have not been significantly affected by anthropogenic pollutants, notably from aviation activities, may be increased significantly by the suborbital flight industry in the future. Studying the residence time of the emitted gases and particles in the atmosphere, temperature responses, interaction of the particles, and potential changes remains a challenge for future scientists. To this end, assessment and modeling techniques and concepts similar to those utilized for quantification of the environmental impacts of emissions from other sources are required.[38]

B. Suborbital Impact

As explained in the previous sections, the proposed designs for suborbital vehicles include a trajectory that vertically extends beyond the Earth's atmosphere. This raises the question of whether these vehicles, when they enter space, can be consid-

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34 William, *supra* note 2, at 27–29; *Atmospheric Layers*, *supra* note 9.

35 *Climate Change Affecting Earth's Outermost Atmosphere*, U. Corp. for Atmospheric Res. [UCAR] (Dec. 11, 2006), http://www.ucar.edu/news/releases/2006/thermosphere.shtml [https://perma.cc/BV8A-EC2Q].

36 *See id.*

37 He QizHi, *Environmental Impact of Space Activities and Measures for International Protection*, 16 J. Space L. 117, 118 (1988).

38 *Assessing Climate Change, Noise & Air Quality Aviation Impacts*, *supra* note 8, at v.

ered potential pieces of debris that cause a threat to other functional space objects. Space debris or other environmental threats to space have not been defined or sufficiently addressed in the international treaties of outer space. In its space debris mitigation guidelines of 2007, the United Nations Committee on the Peaceful Uses of Outer Space has defined space debris as "man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."[39] Pursuant to this definition, suborbital vehicles, like space objects, may create debris by collision or breakups. The important question will be whether the debris produced by suborbital vehicles has the potential to cause harm to functional space objects.

In addition, suborbital activities take place in a region that is located in the lower part of LEO.[40] LEO is also the perfect orbit for operating satellites with high-resolution imaging functions because satellites in LEO can fly over the entire planet.[41] In fact, many human space activities are conducted in LEO.[42] Debris generated at lower altitudes, such as in LEO, will eventually reenter the Earth's atmosphere.[43] Once an object enters the measurable atmosphere, atmospheric drag will slow the orbiting object down rapidly.[44] When returning to Earth, these objects either are incinerated by the atmospheric effect or they survive atmospheric re-entry and crash to Earth, which usually occurs

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39 U.N. Office for Outer Space Affairs, Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, at 1, U.N. Doc. V.09-88517 (2010). This is the same definition of space debris as in the Inter-Agency Space Debris Coordination Committee (IADC) Guideline. Inter-Agency Space Debris Coordination Committee [IADC], *IADC Space Debris Mitigation Guidelines*, at 5, IADC-02-01 (Sept. 2007) (Revision 1).

40 The IADC Space Debris Mitigation Guidelines define LEO as extending from the Earth's surface up to an altitude of 2,000 km, whereas the Interagency Report on Orbital Debris, 1995, expands LEO's limits up to an altitude of 5,500 km above Earth. *See* Office of Sci. & Tech. Policy, Exec. Office of the President, Interagency Report on Orbital Debris 4 (1995).

41 Natalie Pusey, *The Case for Preserving Nothing: The Need for a Global Response to the Space Debris Problem*, 21 Colo. J. Int'l Envtl. L. & Pol'y 425, 426–27 (2010).

42 *Id.*; Lucinda R. Roberts, *Orbital Debris: Another Pollution Problem for the International Legal Community*, 11 Fla. J. Int'l L. 613, 616 (1996–1997).

43 "Unless they are reboosted, satellites in circular orbits at altitudes of 200 to 400 km reenter the atmosphere within a few months . . . . The more mass per unit area of the object, the less the object will react to atmospheric drag." *See* Interagency Report on Orbital Debris, *supra* note 40, at 6.

44 *Id.*

with larger pieces of debris.[45] Considering the altitude at which they will operate, it does not seem probable that the pieces of debris caused by suborbital vehicles, in cases of collision or breakup, pose a risk to orbiting space objects. However, there are chances of collisions between these vehicles and spacecraft and objects launched into space or de-orbiting objects,[46] especially in the absence of an efficient traffic management system for space activities, which may lead to the creation of more debris.[47] Moreover, in cases of collisions or breakups that produce debris, some particles could survive the atmospheric effect and crash to Earth, potentially causing damage to people and property. In this regard, assessments and studies on risk calculation should be carried out for better forecasting of the risk, its magnitude and consequences therefrom, and possible mitigation mechanisms.

IV. REGULATORY RESPONSES

A. The International Regulatory System

As a new technological innovation with unsettled associated legal issues, suborbital flights are not explicitly addressed within the current international regulatory framework.[48] To make the problem even more complex, there is no clarification with respect to the boundary between airspace and outer space. Therefore, scholars must try as best they can to respond to the legal concerns that may be associated with the regular operation of suborbital vehicles in the future. At one end of the spectrum are

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45 *Id.*; Lynda Williams, *Space Ecology: The Final Frontier of Environmentalism*, Nat. Living Mag., at 8, http://www.santarosa.edu/~lwillia2/ecospace.pdf [https://perma.cc/99N9-ZC3L].

46 De-orbit has been defined as "intentional changing of orbit for re-entry of a spacecraft or orbital stage into the Earth's atmosphere to eliminate the hazard it poses to other spacecraft and orbital stages, by applying a retarding force, usually via a propulsion system." *IADC Space Debris Mitigation Guidelines*, *supra* note 39, at 3.4.2.

47 The other side of the problem is that, in addition to physical damages that debris may cause, there is a chance that debris could knock out suborbital vehicles. In LEO, "objects travel at such rapid speeds that a piece of debris just [one] centimeter in diameter could disable a functioning satellite upon collision." Pusey, *supra* note 41, at 430.

48 The reason for this lack of legal clarity in respect to suborbital flights might be that at the time the legal documents that form the framework for both aviation and space activities were drafted, large-scale commercial use of space and orbital and suborbital flights were not probable and, therefore, did not constitute a concern. Steven Freeland, *Fly Me to the Moon: How Will International Law Cope with Commercial Space Tourism?*, 11 Melb. J. Int'l L. 90, 90 (2010).

those scholars who incorporate the legal issues of these flights within the international air law regime, while at the other end are those who believe these flights should be included within the existing international space law regime.[49] A third approach suggests applying both legal regimes in order to regulate suborbital flights, but this will obviously be accompanied by some practical complexities and hurdles.[50] This is because the two legal regimes are very much distinct, with fundamentally different legal principles. While the international air law regime, which is primarily defined by multilateral treaties such as the Chicago Convention, is based on the principle of the "sovereignty" of individual states,[51] the international space law regime, with the Outer Space Treaty as the pivotal instrument of this regulatory regime, incorporates concepts such as "freedom of exploration and use," "non-appropriation," and "Province of Mankind."[52] In

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[49] In their article, Masson-Zwaan and Freeland vote for space law as the applicable legal regime for suborbital flights: "[F]or the interim, we believe that the best approach would be to apply space law to the entire orbital or suborbital international flight, simply on the basis of the proposed function of the vehicle—namely that it involves a flight in(to) outer space." Masson-Zwaan & Freeland, *supra* note 5, at 1603. Stephen Gorove, taking a functional approach, has suggested that for objects having the aim of transportation, air law might be the competent regime: "[I]t may be suggested that if the aerospace object is used as an aerospace plane for the primary purpose of operating as an aircraft engaged in earthbound transportation and only incidentally reaches the fringes of outer space, air law should be applicable to it. However, it stands to reason that such objects may be expected to comply with space debris mitigation, rules of the road, and other requirements while operating briefly around the fringes of outer space. . . . If the primary function of the aerospace object was to operate as a spacecraft, then air law would not be applicable to it except in situations in which the craft returns in a non-accidental situation to a non-launching state." Stephen Gorove, *Aerospace Object —Legal and Policy Issues for Air and Space Law*, 25 J. SPACE L. 101, 106, 110 (1997).

[50] THE NEED FOR AN INTEGRATED REGULATORY REGIME FOR AVIATION AND SPACE: ICAO FOR SPACE? 50 (Ram S. Jakhu et al. eds., 2011) [hereinafter THE NEED FOR AN INTEGRATED REGULATORY REGIME]. Some commentators argue that there is no need for demarcation of the air and space, and the location of the vehicle simply determines the applicable regime: "It would not be logical to apply international air law, or national [air law], liability regimes to a spaceplane just because it happened to become involved in an accident in airspace while en route to or from outer space." Elizabeth Kelly, The Spaceplane: The Catalyst for Resolution of the Boundary and 'Space Object' Issues in the Law of Outer Space? (Nov. 1998) (unpublished LL.M. thesis, McGill University) (on file with McGill University).

[51] Convention on International Civil Aviation art. I, Dec. 7, 1944, 15 U.N.T.S. 295 [hereinafter Chicago Convention].

[52] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies arts. I & II, Jan. 27, 1967, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

addition, there are fundamental differences regarding liability principles in each legal system,[53] and inconsistencies between the two regimes do not end there.[54] Accordingly, the present international regulatory system needs to be modified to embrace the technological novelties in the fields of air and space activities.

Nevertheless, there are provisions and principles in current treaty law that may relate to environmental protection with respect to the operation of suborbital flights. For example, the Outer Space Treaty contains a brief mention of environmental protection in Article IX by requiring the Member States to avoid harmful contamination of space when pursuing research and exploration of outer space.[55] Besides this reference to the preservation of outer space, Article VI of the Outer Space Treaty assumes that Member States are responsible for the space activities of their nationals. Article VI and other provisions of the Outer Space Treaty preclude Member States and their nationals from following an inconsiderate and self-serving approach in their activities in outer space. In sum, Member States are obliged to ensure that their space activities comply with the Outer Space Treaty, recognize international law as it applies to the State, and both authorize and supervise their nongovernmental activities.[56]

Additionally, Articles VII and VIII establish a legal basis for holding the launching Member States internationally liable for damages to other Member States. Article VII provides that the liability is for "the damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including

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53 There is a two-fold liability system for the damages caused through space activities: absolute liability for the injuries and damages caused on the surface of Earth or to the aircrafts in flight and fault-based liability for accidents in outer space. *See* Convention on International Liability for Damage Caused by Space Objects arts. II & III, Mar. 29, 1972, 961 U.N.T.S. 187 [hereinafter Liability Convention]. In contrast, the Warsaw and Montreal Conventions, founding the liability system in air law, created a fault-based limited liability system. The Rome Convention, on surface damage by foreign aircraft, provides for capped absolute liability.

54 The principles and provisions concerning registration issues, rights of flight participants, as well as airworthiness and spaceworthiness are other examples of different approaches between the two legal systems.

55 Outer Space Treaty, *supra* note 52, art. IX.

56 Ronald L. Spencer, *State Supervision of Space Activity*, 63 A.F. L. REV. 75, 82 (2009).

the Moon and other celestial bodies."[57] Because this obligation is very general in nature, it might be possible to interpret it in a way to extend such liability to the environmental consequences of space activities.

Likewise, the Liability Convention defines the term "damage" as "loss of life, personal injury or *other impairment of health*."[58] It is not clear what kind of health effects were intended by the drafters of the Convention as capable of "impairment," but this term also seems to be general and open to interpretation in a way that includes the health effects directly or indirectly caused by environmental consequences of space activities. Finding the answer to this legal uncertainty will add to existing discussions over extending the Liability Convention to the damages caused by space debris. However, as already mentioned, it is first important to determine whether suborbital flights can even be considered as space activities for them to be covered under the current regulatory framework.

The air law regime is no clearer. Although the air law regime is quite detailed and well developed in various areas, including regulations regarding noise and emissions,[59] it is not clear whether control of the emissions and the possible effects of the operation of suborbital vehicles fall within the jurisdiction of this regulatory system. For example, the definition of an aircraft in Annex 7 to the Chicago Convention is "a machine [that] derives support in the atmosphere from the reactions of the air."[60] This definition does not incorporate suborbital vehicles with the designs and characteristics that are planned and proposed to this date.[61] Therefore, it is currently not possible to include suborbital vehicles within the environmental regulations of air law, such as Annex 16 to the Chicago Convention, without promulgating necessary changes and amendments.

Further attempts to avoid leaving this nascent industry unregulated from an environmental perspective leads to the potential application of international environmental law. As some schol-

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[57] Outer Space Treaty, *supra* note 52, art. VII.

[58] Liability Convention, *supra* note 53, art. I (emphasis added).

[59] "The international legal regime governing air transport on issues such as liability, security, navigation, and air traffic management are well developed, and set forth in various conventions, treaties, and various 'soft law' standards." THE NEED FOR AN INTEGRATED REGULATORY REGIME, *supra* note 50, at 49.

[60] ICAO, *Aircraft Nationality and Registration Marks*, at 1, ICAO Doc. Annex 7 (4th ed. July 1981).

[61] As explained, suborbital vehicles are not pure aircraft or spacecraft. Instead, they mix some characteristics of both.

ars believe, legal techniques of regulating correlations between man and his environment require that environmental law be applicable not only on Earth, but also extraterrestrially and even outside the Solar System.[62] Therefore, examining the application of the international environmental law to suborbital flights might be a step in filling this legal gap.[63]

There are general rules and principles that urge states to act in an environmentally conscious way when exploring the new realms of technology and science or exploiting natural resources—the Declaration of the United Nations Conference on the Human Environment, Stockholm 1972 (Stockholm Declaration) is one example.[64] This Declaration asks for cessation of "the discharge of toxic . . . [and] other substances and [of] the release of heat, in such quantities or concentrations as to exceed the capacity of the environment to render them harmless."[65] The Declaration goes further by assuming that states are responsible "for ensur[ing] that activities within their jurisdiction or control do not cause damage to the environment of other states or to areas beyond the limits of national jurisdiction."[66] Similarly, the Rio Declaration on Environment and Development of 1992 (Rio Declaration) repeats this emphasis on ensuring the non-harmful activities of the nationals of states to the environment of other states and beyond.[67] Principle 15 of the Rio Declaration further provides that "lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation," calling for a "precautionary approach" to be taken by states "[w]here there are threats of serious or irreversible damage."[68] This approach is an expansion of the "preventive approach," which argues that prevention of

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[62] Mate Julesz, *Space Waste and Environmental Space Law*, 2 JURA A PECSI TUDOMÁNYEGYETEM ÁLLAM-ÉS KARÁNAK TUDOMÁNYOS LAPJA, JURA, 39, 40 (2010) (Hung).

[63] There are international environmental treaties on a variety of areas that might be relevant to suborbital flights. They include conventions about protection of the atmosphere and climate change or ozone depletion effects, protection against hazardous substances or nuclear products, and the hostile uses of the environment.

[64] *See* United Nations Conference on the Human Environment, Stockholm, Swed., June 5–16, 1972, *Declaration of the United Nations Conference on the Human Environment*, U.N. Doc. A/CONF.48/14/Rev.1 (Vol.1), Annex I [hereinafter *Stockholm Declaration*].

[65] *Id.* princ. 6.

[66] *Id.* princ. 21.

[67] *Rio Declaration*, *supra* note 2, princ. 2.

[68] *Id.* princ. 15.

damage to the environment is always better than restoration after damage occurs.[69] The "precautionary principle" is based on the idea that environmental matters should be taken into consideration even if there is a lack of certainty.[70] According to environmental legal experts, the precautionary principle is one of the founding principles of international environmental law and, thus, needs to be taken into account by states.[71]

In addition to these declarations, which constitute an important part of international environmental law, there have been other international efforts to address the environmental concerns of the international community. Agenda 21, which was adopted by the same United Nations Conference on Environment and Development of 1992 that adopted the Rio Declaration, refers to the commitment of states to manage chemicals in an environmentally sound manner and encourages conducting transparent risk assessments and management procedures.[72] Ten years later, the Johannesburg Declaration on Sustainable Development again put emphasis on mutual efforts for environmental protection and considered environmental protection as one of the three pillars of sustainable development.[73] As explained in previous sections, the possible negative effects from suborbital vehicles, unless frequently operated, will probably be minimal. Nevertheless, while the above-mentioned international declarations are not binding and do not have the enforceability of treaty law,[74] it can be argued that the obligation not to cause environmental harm is a principle of international custom and

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69 ELLI LOUKA, INTERNATIONAL ENVIRONMENTAL LAW: FAIRNESS, EFFECTIVENESS, AND WORLD ORDER 50 (2006).

70 *Id.*; SIMON MARSDEN, STRATEGIC ENVIRONMENTAL ASSESSMENTS IN INTERNATIONAL AND EUROPEAN LAW: A PRACTITIONER'S GUIDE 52 (2008).

71 FITZMAURICE, *supra* note 2, at 1–10. There is still a controversy with respect to this principle and its status in international environmental law. *See* LOUKA, *supra* note 69, at 50–51; MARSDEN, *supra* note 70, at 52.

72 United Nations Conference on Environment and Development, Rio de Janeiro, Braz., Aug. 12, 1992, *Agenda 21*, U.N.Doc. A/CONF.151/26 (Vol. I-III), pmbl.

73 World Summit on Sustainable Development, Johannesburg, S. Afr., Sept. 4, 2002, *Johannesburg Declaration on Sustainable Development*, U.N.Doc.A/CONF.199/20, Annex.

74 The accepted sources of international law are those envisaged in Article 38 of the Statute of the International Court of Justice; they include:

> a. international conventions, whether general or particular, establishing rules expressly recognized by the contesting states;
> b. international custom, as evidence of a general practice accepted as law;
> c. the general principles of law recognized by civilized nations;

is therefore binding.[75] Given the complexity and uncertainty of present international law, the international environmental obligations of states with respect to suborbital flights must be further clarified and defined.

B. National Regulatory System

Since there is currently no uniform comprehensive international regime in place to regulate suborbital flights, "each country has the sovereign right to regulate human suborbital flights operating within its airspace."[76] In order to control the emissions generated from the engines of suborbital vehicles, there are mandatory requirements and standards that have been adopted for engine licenses and certifications for the operation of aircraft and spacecraft.[77] These regulations were designed to serve various aims such as protection of public health, safety, and compliance with international obligations of countries. The licensing is carried out pursuant to national regulatory procedures and varies from country to country. Currently, the United States has taken the lead in adopting specific regulations related to reusable launch vehicles. If other countries plan to develop suborbital vehicles that are ready to start experimental flights or regular operation, they will need to determine whether they should pass laws specifically designed to regulate such vehicles or whether they can incorporate them into their existing national regulations on aviation or space activities.

In Europe, the Treaty of the European Union[78] "allows for development of common policies among [M]ember [S]tates of the European Union (EU) in all sectors of transport, including aviation," and some organizations, such as the European Avia-

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> d. subject to the provisions of Article 59, judicial decisions and the teachings of the most highly qualified publicists of the various nations, as subsidiary means for the determination of rules of law.

Statute of the International Court of Justice, art. 38, para. 1.

[75] David Hunter et al., International Environmental Law and Policy 502 (3d ed. 2007).

[76] Tanja Masson-Zwaan & Rafael Moro-Aguilar, Presentation delivered at the 2nd IAA Symposium on Private Human Access To Space, Arcachon, France, May 30–June 1, 2011: Practical Solutions for the Regulation of Private Human Sub-Orbital Flight: A Critical Analysis, at 1.

[77] *See IPCC Special Report: Aviation and the Global Atmosphere*, *supra* note 13, at 11.

[78] *See generally* Consolidated Version of the Treaty on the Functioning of the European Union, Title VI, Official Journal of the European Union 326/84 (2012).

tion Safety Agency (EASA), have been developed with this aim.[79] Therefore, it can be argued that it is possible to incorporate suborbital flights into existing regulations but, of course, with necessary modifications, with EASA having the mandate to regulate suborbital flight activities.[80] The European Space Agency (ESA), the European authority for regulating space activities, and EASA, which is responsible for regulating the safety and environmental aspects of aviation, have both classified suborbital flights under the category of aviation.[81] The EU, however, has not yet taken a position on the matter. Depending on whether suborbital flights are considered aviation or space activities, the EU will have different competencies on the respective flights.[82]

As for transportation generally, to which aviation belongs, the EU has been vested with the regulatory competence to regulate the industry, and the EU's primacy in regulating preempts the Member States from exercising their own competence. On the other hand, in terms of space activity, the EU's competence coexists with Member States, which will produce different outcomes.[83] As the operation of suborbital vehicles, and the involvement of the EU and its Member States, approaches, the more urgent the need will be for a regulatory response from the European countries. It is likely that the authority to regulate suborbital flights in Europe will be vested in EASA, which follows Commission Regulation (EU) No 748/2012 and its subsequent amendments in verifying the compliance of aircraft with safety and environmental protection requirements.[84] However, it has also been suggested that EASA's regulatory role will cease when a suborbital vehicle enters outer space and, thus, will not extend to the entire flight.[85]

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[79] Jean-Bruno Marciacq et al., Accommodating Sub-Orbital Flights into the EASA Regulatory System (Dec. 2007) (unpublished article) (on file with author).

[80] *Id.*

[81] Masson-Zwaan & Moro-Aguilar, *supra* note 76, at 1, 11.

[82] Tanja Masson-Zwaan, *Regulation of Sub-orbital Space Tourism in Europe: A Role for EU/EASA?*, 35 Air & Space L. 263, 267–68 (2010).

[83] *Id.*

[84] Commission Regulation (EU) No 748/2012, which replaces Commission Regulation (EC) No. 1702/2003, "lay[s] down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts[,] and appliances, as well as for the certification of design and production." Marciacq et al., *supra* note 79, at 1.

[85] *See* Masson-Zwaan, *supra* note 82, at 271; Masson-Zwaan & Moro-Aguilar, *supra* note 76, at 14.

C. UNITED STATES LAW

The United States, being heavily involved in space-related activities, has taken an active role in promulgating national regulations with respect to space tourism and the launch industry. For example, the Commercial Space Launch Act Amendments of 2004[86] vested the Department of Transportation (DOT) with the authority to oversee, license, and regulate commercial launch activities and operation of launch sites carried out by U.S. citizens or within U.S. territory. These responsibilities are exercised through the Associate Administrator for Commercial Space Transportation of the Federal Aviation Administration (FAA/AST) of DOT.[87] FAA/AST imposes its delegated responsibilities by issuing commercial space transportation licenses or experimental permits for which necessary requirements have to be fulfilled.[88] In terms of how the environmental impacts of reusable launch vehicles are dealt with in the U.S. regulatory system, the National Environmental Policy Act of 1969 (NEPA) is part of U.S. environmental law that requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed projects and reasonable alternatives to those actions.[89] Section 102(2)(C) requires detailed analysis for proposed "major federal actions"[90] that significantly affect the quality of the

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[86] 118 Stat. 3974 (2004). This Act is the re-codified version of the Commercial Space Launch Act of 1984.

[87] 49 U.S.C. §§ 70101–70121 (2009).

[88] *Office of Commercial Space Transortation, Licenses, Permits & Approvals*, FAA, http://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/ [https://perma.cc/23MB-G6V3].

[89] The purpose of this Act is "[t]o declare a national policy [that] will encourage productive and enjoyable harmony between man and his environment; to promote efforts [that] will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality." National Environmental Policy Act of 1969, Pub. L. No. 91-190, § 82, 83 Stat. 852 (1970) (codified as amended at 42 U.S.C. § 4321 (2002)) [hereinafter NEPA].

[90] In the Terminology and Index of Regulations for Implementing NEPA, "major federal action" is defined as including "actions with effects that may be major and . . . are potentially subject to federal control and responsibility. Major reinforces but does not have a meaning independent of significantly (§ 1508.27). Actions include the circumstance where the responsible officials fail to act[,] and that failure to act is reviewable by courts or administrative tribunals under the Administrative Procedure Act or other applicable law as agency action." 40 C.F.R. § 1508.18 (2005).

human environment.[91] To this end, there is a detailed statement known as an Environmental Impact Statement (EIS), which is prepared by the agency involved in the proposed project.[92] The FAA and the licensing of new space technologies are no exception. The reason being that licensed launches constitute a major federal action, and under NEPA, major federal actions are required to be examined concerning their potential environmental impacts.[93] In fact, "the FAA is responsible for analyzing the environmental impacts associated with licensing proposed commercial launches or proposed commercial launch sites."[94] The environmental documents that NEPA requires as part of the review process include Environmental Assessments (EAs), EISs, Findings of No Significant Impact (FONSIs), and Categorical Exclusions (CATEXs).[95] For launch activities, FAA/AST, in addition to NEPA, also requires that operators comply with The Council on Environmental Quality (CEQ), Regulations for Implementing NEPA,[96] FAA Environmental Impacts: Policies and Procedures,[97] Executive Order 12114, Environmental Effects Abroad of Major Federal Actions, and other related environ-

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[91] NEPA, *supra* note 89, § 102(2)(c).

[92] *National Environmental Policy Act*, U.S. Envtl. Protection Agency, http://www.epa.gov/compliance/nepa/ [https://perma.cc/269U-D69G].

[93] *See* NEPA, *supra* note 89, § 102(2)(c); *see also Environmental Review for Licensed/Permitted Commercial Space Transportation Activities*, FAA, http://www.faa.gov/about/office_org/headquarters_offices/ast/environmental/review/ [https://perma.cc/3L4Y-RQ3H] [hereinafter *Environmental Review*].

[94] Office of the Assoc. Adm'r for Commercial Space Transp., FAA, U.S. Dept. of Transp., Revised Guidelines for Compliance with the National Environmental Policy Act and Related Environmental Review Statutes for the Licensing of Commercial Launches and Launch Sites (2001).

[95] NEPA, *supra* note 89; Exec. Order No. 12114, 44 Fed. Reg. 18722 (Mar. 21, 1979), *reprinted as amended in* 42 U.S.C. § 4321 (2015) [hereinafter Order 12114]. With respect to the Categorical Exemptions, the Act states: "Agency procedure under Section 2-1 may provide for categorical exclusions and for such exemptions in addition to those specified in subsection (a) of this Section as may be necessary to meet emergency circumstances, situations involving exceptional foreign policy and national security sensitivities, and other such special circumstances. In utilizing such additional exemptions agencies shall, as soon as feasible, consult with the Department of State and the Council on Environmental Quality." There are also other documents, such as the Proposal or Notice of Action, that are applicable to the environmental assessment required when issuing launch licenses and permits.

[96] *See* 40 C.F.R. § 1508 (2005).

[97] Order 12114, *supra* note 95, at 18722. As explained in the Order itself, Order 1050.1E "supplements the CEQ regulations by applying them to FAA programs." FAA Order 1050.1E, para. 9 (June 8, 2004) (canceled by FAA Order 1050.1F).

mental laws, regulations, and orders applicable to FAA actions.[98] Additionally, Executive Order 12114 requires the FAA to consider the environmental effects of major federal actions outside the geographical borders of the United States and its territories that could significantly affect "the environment of the 'global commons' beyond the jurisdiction of any nation" or that could affect a foreign nation in certain cases of a major federal action abroad.[99] This Executive Order provides strong support for environmental regulation of space activities, which can be considered part of the global commons.[100] Finally, after the FAA environmental requirements are met and all the necessary information and documents are provided, an FAA/AST official determines the environmental impacts of a proposal either by issuing a FONSI or a Record of Decision (ROD), which is a public record of a decision indicating final approval of a proposed action analyzed in an EIS.[101] This decision will form part of the license or experimental permit evaluation.[102]

As evidenced by its numerous rules and regulations, the United States has a comprehensive regulatory system with respect to environmental protection in many different fields, including launch activities. Because suborbital vehicles are classified as launch vehicles under U.S. law, they are licensed or permitted by the FAA/AST, which is the same governmental office that approves licenses and permits for other launch vehicles, both reusable and expendable.[103] Similar to other launch activities, environmental analysis and assessments are also part of the licensing or permitting process for suborbital vehicles. For example, in May 2012 the FAA issued its final environmental assessment for the launch and re-entry of *SpaceShipTwo* and *WhiteKnightTwo* carrier aircraft at the Mojave Air and Space Port.[104] A similar assessment was issued in November 2011 for

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[98] *Environmental Review*, *supra* note 93, at 1.

[99] Order 12114, *supra* note 95, at 18722.

[100] David Enrico Reibel, *Environmental Regulation of Space Activity: The Case of Orbital Debris*, 10 STAN. ENVTL. L. J. 97, 128–29 (1991).

[101] *See Environmental Review*, *supra* note 93, at 1.

[102] *See id.*

[103] *Office of Commercial Space Transportation: Launch or Reentry Vehicles*, FAA, http://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/launch_reentry/#reusable [https://perma.cc/3J4B-RZFT].

[104] FAA, FINAL ENVIRONMENTAL ASSESSMENT FOR THE LAUNCH AND REENTRY OF SPACESHIPTWO REUSABLE SUBORBITAL ROCKETS AT THE MOJAVE AIR AND SPACE PORT (Apr. 30, 2012) [hereinafter FINAL EA FOR THE LAUNCH AND REENTRY OF SPACESHIPTWO].

the experimental assessment of SpaceX concerning the operation of its vehicle, *Grasshopper*; the purpose of this assessment was to conduct suborbital launches and landings.[105] In both cases, the FAA determined that issuing experimental permits and/or launch licenses to operate the proposed vehicles would not significantly impact the quality of the human environment and, therefore, preparation of an EIS was not required.

The FAA also issues FONSIs with EAs incorporated by reference.[106] The inquiry on probable environmental consequences in these assessments has included many variables such as air quality; biological resources; hazardous materials; pollution prevention; solid waste; historical, architectural, archaeological, and cultural resources; land use; noise and compatible land use; light emissions and visual resources; natural resources and energy supply; socioeconomics, environmental justice, and children's environmental health and safety; and water resources.[107]

In the case of *SpaceShipTwo*, the FAA, by using its emission modeling systems, examined the emissions from *SpaceShipTwo*, *WhiteKnightTwo*, and the support aircraft involved in the flight, in both the lower and upper atmosphere.[108] It was concluded that the emissions from operations of *WhiteKnightTwo*, the support aircraft, and *SpaceShipTwo* in the upper atmosphere could affect global climate change. However, the total amount of emissions was a very small fraction of national and global emissions; thus, the adverse impacts would be negligible.[109] This was also true in terms of noise. Noises produced by *SpaceShipTwo*, *WhiteKnightTwo*, and the support aircraft were estimated to be insignificant and, therefore, would not be a concern at the time.[110] Similar examinations were carried out for the experimental assessment of *Grasshopper*, and they likewise led to the

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105 FAA, Final Environmental Assessment for Issuing an Experimental Permit to SpaceX for Operation of the Grasshopper Vehicle at the McGregor Test Site (Nov. 4, 2011) [hereinafter Final EA for Issuing an Experimental Permit to SpaceX].

106 *Id.*; Final EA for the Launch and Reentry of SpaceShipTwo, *supra* note 104.

107 Final EA for the Launch and Reentry of SpaceShipTwo, *supra* note 104; Final EA for Issuing an Experimental Permit to SpaceX, *supra* note 105.

108 Final EA for the Launch and Reentry of SpaceShipTwo, *supra* note 104, at 26–32.

109 *Id.* at 30.

110 *Id.*

conclusion that the environmental impacts of launching and landing *Grasshopper* would be negligible.[111]

As explained previously, the FAA is also responsible for licensing launch sites. In 2006, the FAA issued an EA for the experimental permits and licenses of a private launch site proposed by Blue Origin "to launch reusable launch vehicles on suborbital, ballistic trajectories to altitudes in excess of 99,060 meters."[112]

These are the sole national regulations the country has promulgated for regulating different aspects of suborbital flights, including environmental impacts, which is no surprise when considering the United States' leading role in commercial space activities. However, only the passage of time will determine the extent to which the procedures in place and the U.S. regulatory system can address the environmental concerns regarding frequent operation of suborbital vehicles. Large numbers of suborbital flights will have to occur, and data and statistics will need to be collected to develop a comprehensive and efficient regulatory system for these flights.

V. INEFFICIENCY OF THE "AIR-OR-SPACE APPROACH" IN ADDRESSING ENVIRONMENTAL CONCERNS

In the absence of a regulatory system specifically developed to regulate different aspects of suborbital flights, some legal scholars have attempted to select either air or space law regimes as competent to regulate this emergent technology. This is likely not an ideal approach in terms of regulation, however, at least when it comes to the protection of the environment. For example, considering that the trajectory in a suborbital flight extends from the surface of the Earth to outer space, a suborbital vehicle might have environmental impacts on the surface of the Earth, different levels of the atmosphere, and outer space; a good illustration is the creation of a piece of debris from a suborbital flight that falls back to Earth, causing environmental damage. In such a scenario, trace of suborbital human flight activities could be found in both the air and space law regimes. Therefore, from an environmental point of view, it may well not be practical or efficient to apply regulations of one legal regime to the entire journey.

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111 FINAL EA FOR ISSUING AN EXPERIMENTAL PERMIT TO SPACEX, *supra* note 105.

112 FAA, FINAL ENVIRONMENTAL ASSESSMENT FOR THE BLUE ORIGIN WEST TEXAS COMMERCIAL LAUNCH SITE (Aug. 29, 2006).

Additionally, it has been argued that "insofar as the trajectories of these vehicles are purely vertical and do not intend to cross any international frontiers," the activity is therefore not international in scope and could be regulated solely through national legal systems.[113] This might not be true, however, regarding protection of the environment. In terms of international law, air and outer space are shared, common sources among states, so suborbital vehicles are associated with transboundary environmental pollution.[114] Avoiding transboundary pollution is a rule that stipulates that one State cannot allow activities under its jurisdiction or control to harm the environment of a neighboring country or areas beyond its national jurisdiction.[115] Moreover, some of the environmental effects that may arise from operation of the suborbital flights, such as climate change, are global environmental threats, and individual countries are responsible for avoiding them. Indeed, the obligation to avoid transboundary pollution is allegedly part of international custom.[116] According to some scholarly comments:

> One of the well-recognized principles of customary international law included for example, in many international environmental law conventions, is the prohibition against trans-boundary harm, meaning a State cannot allow its territory to be used in a manner which causes injury to another State. As is the case with many general principles of customary international law, the prohibition against trans-boundary harm is significantly broader than individual conventions, environmentally-based or otherwise, that may incorporate it.[117]

The international community is based on cooperation, and when there is a threat that involves more than one state, it is important to develop an international solution to the problem that will serve the interests of all. In other words, what concerns all must be approved by all: *caveat humana dominandi, quod omnes tangit ab omnes approbatur*. Promoting a similar ideology, the Stockholm Declaration provides that "[i]nternational matters concerning the protection and improvement of the environ-

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113 Masson-Zwaan & Moro-Aguilar, *supra* note 76, at 3.

114 Louka, *supra* note 69, at 90.

115 Hunter et al., *supra* note 75, at 539.

116 *Id.*

117 The Need for an Integrated Regulatory Regime, *supra* note 49, at 47. On the issue of transboundary air pollution, there is only one international convention, the Convention on Long-Range Transboundary Air Pollution, concluded in 1979, with four protocols added to it. *See* Convention on Long-Range Transboundary Air Pollution, Nov. 13, 1979, 1302 U.N.T.S. 217.

ment should be handled in a cooperative spirit by all countries, big and small, on an equal footing."[118] Consequently, the frequent operation of suborbital vehicles will eventually lead to the necessity for states to engage in such efforts at the international level.

It is obvious that the law needs to adapt to current and emerging technological innovations and that environmental law specifically must be innovative and adaptable to science with respect to both the terrestrial environment and other parts of the universe.[119] In regulating the negative anthropogenic effects of suborbital flights on the environment, it is important to consider two criteria. First, in regulating the effects of these flights, especially regarding operational or technology-related abatement measures, there should be a balance of many factors. For example, the regulator needs to balance factors controlling noise and emissions on the one hand with reliability and safety standards on the other.[120]

Second, the growth of this nascent industry should not be impeded by overregulation. While both aviation and space activities contribute to anthropogenic pollution, if such activities are subject to cumbersome and unnecessary regulatory controls, they may not be able to develop and flourish. The current projects for suborbital flights include entertainment and tourism, but there are also proposals for general suborbital transportation in the future. Even more importantly, considering their altitude and the microgravity experience they offer, these flights have the potential to contribute to scientific research.[121] These research possibilities include: (1) spectroscopic measurements of the stars and other benefits that result from a suborbital trip with a telescope on board; (2) monitoring the human body's response to changes in gravity and other biological and human physiology types of research and physics experiments; and (3) the opportunity for space object developers to test the technical aspects of their plans or to even launch objects such as satellites from high altitudes.[122] Virgin Galactic, for example, argues that the flights offered by *SpaceShipTwo* will open up access to an area

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118 *Stockholm Declaration*, *supra* note 64, princ. 24.

119 Julesz, *supra* note 62, at 40.

120 This is the same challenge the regulators of aviation and space activities face. *See, e.g.*, Miller, *supra* note 33, at 724.

121 Katherine Sanderson, *Science Lines up for a Seat to Space*, 436 NATURE 716, 716–17 (2010).

122 *Id.*

previously known as the "ignosphere," which will enable scientists to carry out research on climate change and other negative anthropogenic effects at an altitude that was not previously possible.[123] Therefore, it is vital to assist an industry that has excellent potential for serving humankind by enacting both efficient and inclusive regulations that are not burdensome nor unnecessary.

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123 *Environment: Making Space for Earth and the Environment, supra* note 21.